```
constant n_points;
    constant n_classes;

    probability rho[n_classes];

    random mu_x[n_classes];
    random mu_y[n_classes];
    random sigma_x[n_classes];
    random sigma_y[n_classes];

    random c[n_points];

    data x[n_points]
    data y[n_points]

    c  ~ discrete(rho)

    x[i] ~ gaussian(mu_x[c[i]], sigma_x[c[i]];
    y[i] ~ gaussian(mu_y[c[i]], sigma_y[c[i]];

    optimize P(x, y | rho, mu_x, mu_y, sigma_x, sigma_y)
     for rho, mu_x, mu_y, sigma_x, sigma_y;
```

Fig. 2. Example specifications.

Propellant Preservation for Mars Missions

Peter Kittel

The last few years have seen extensive technology planning for human missions to Mars. These missions will make extensive use of cryogenic propellants, some of which will be transported to Mars. Additional propellants will be manufactured, liquefied, and stored on Mars. The missions that use these propellants could start early this century. Although many of the plans are still evolving, it has been possible to derive a set of cooler requirements. Recent estimates of these requirements are given here along with a discussion of whether the requirements can be met with existing coolers and coolers currently being developed.

In recent years, a variety of transportation scenarios have been considered. The analysis reported here relates to one of the more promising nonnuclear options. It makes use of solar electric propulsion (SEP). The SEP baseline concept follows:

1. A SEP tug boosts the TMI (trans-Mars injection) stage to a highly elliptical orbit. This phase requires 400 days of propellant storage for the TMI piloted stage and 250 days for the TMI cargo stages.

2. The ascent and descent stages require about 580 days of propellant storage for the piloted mission and 550 days for the cargo case. These stages use oxygen (O_2) and methane (CH_4) for propellants.

3. The TEI (trans-Earth injection) stage requires a storage duration of 1200 days. This stage uses hydrogen (H_2) as the propellant.

4. All tanks are cooled by cryocoolers to eliminate boil off.

5. The tank design is standardized to 3.29-meter-diameter spheres.

Fixing the volume results in the stages having multiple tanks, with many of the tanks full at launch.

A thermal model was used to estimate the cooler requirements. This model could estimate the tank size and mass for MLI (multilayer insulation) insulated tanks with and without coolers. The cooling power and the mass of the power source and radiators were included for ZBO (zero boil-off) storage. In the first case, the volume of the tank was variable. The volume was adjusted until it was large enough to accommodate the boil-off during the mission and still preserve the required propellant until it was needed. In the latter case, the volume was fixed. An optional cooled shield has been included in the model for hydrogen tanks.

The results of the model are presented in Table 1. Pulse tube coolers that can meet these requirements are being developed.

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Table 1. Minimum set of coolers assuming 250 kelvin heat rejection temperature

Cooler	Cooler Power (Watts)	Temperature (kelvin)
Single stage	11.8	97.2
Two-stage		
First stage	18.6	85
Second-stage	1.2	22.8